METHOD AND APPARATUS FOR INTERNETWORKED WIRELESS INTEGRATED NETWORK SENSOR (WINS) NODES

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional application Ser. No. 60/158,013, filed Oct. 6, 1999, U.S. Provisional application Ser. No. 60/170,865, filed Dec. 15, 1999, U.S. Provisional application Ser. No. 60/208,397, filed May 30, 2000, U.S. Provisional application Ser. No. 60/210, 296, filed Jun. 8, 2000, U.S. patent application Ser. No. 09/684,706, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,565, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/685,020, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/685,019, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,387, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,490, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,742, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/685,018, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,388, filed Oct. 4, 2000, U.S. patent application Ser. No. 09/684,162, filed Oct. 4, 2000, and U.S. patent application Ser. No. 09/680,608, filed Oct. 4, 2000, all of which are incorporated by reference.

GOVERNMENT LICENSE RIGHTS

The United States Government may have certain rights in some aspects of the invention claimed herein, as the invention was made with United States Government support under award/contract number DAAD 16-99-C-1024 issued by US AMCAC NATICK Contracting Division.

BACKGROUND

1. Field of the Invention

This invention relates to the field of intelligent networks that include connection to the physical world. In particular, the invention relates to providing distributed network and Internet access to sensors, controls, and processors that are embedded in equipment, facilities, and the environment.

2. Description of the Related Art

Sensor networks are a means of gathering information about the physical world and then, after computations based upon these measurements, potentially influencing the physical world. An example includes sensors embedded in a control system for providing information to a processor. The Wireless Integrated Network Sensor (WINS) development was initiated in 1993 under Defense Advanced Research Projects Agency (DARPA) program support. The Low-power Wireless Integrated Microsensors (LWIM) program pioneered the development of WINS and provided support for the development of fundamental low power microelectro-mechanical systems (MEMS) and low power electronics technology. The LWIM program supported the demonstration of the feasibility and applicability of WINS technology in defense systems. See: K. Bult, A. Burstein, D. Chang, M. Dong, M. Fielding, E. Kruglick, J. Ho, F. Lin, T.-H. Lin, W. J. Kaiser, H. Marcy, R. Mukai, P. Nelson, F. Newberg, K. S. J. Pister, G. Pottie, H. Sanchez, O. M. Stafsudd, K. B. Tan, C. M. Ward, S. Xue, J. Yao, "Low Power Systems for Wireless Microsensors", Proceedings of International Symposium on Low Power Electronics and Design, pp. 17–21, 1996; J. G. Ho, P. R. Nelson, F. H. Lin, D. T. Chang, W. J. Kaiser, and O. M. Stafsudd, "Sol-gel derived lead and calcium lead titanate pyroelectric detectors on silicon MEMS structures", Proceedings of the SPIE, vol. 2685, pp. 91–100, 1996; D. T. Chang, D. M. Chen, F. H. Lin, W. J. Kaiser, and O. M. Stafsudd "CMOS integrated infrared sensor", Proceedings of International Solid State Sensors and Actuators Conference (Transducers '97), vol. 2, pp. 1259–62, 1997; M. J. Dong, G. Yung, and W. J. Kaiser, "Low Power Signal Processing Architectures for Network Microsensors", Proceedings of 1997 International Symposium on Low Power Electronics and Design, pp. 173–177, 1997; T.-H. Lin, H. Sanchez, R. Rofougaran, and W. J. Kaiser, "CMOS Front End Components for Micropower RF Wireless Systems", Proceedings of the 1998 International Symposium on Low Power Electronics and Design, pp. 11–15, 1998; T.-H. Lin, H. Sanchez, R. Rofougaran, W. J. Kaiser, "Micropower CMOS RF components for distributed wireless sensors", 1998 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium, Digest of Papers, pp. 157–60, 1998; (Invited) G. Asada, M. Dong, T. S. Lin, F. Newberg, G. Pottie, H. O. Marcy, and W. J. Kaiser, "Wireless Integrated Network Sensors: Low Power Systems on a Chip", Proceedings of the 24th IEEE European Solid-State Circuits Conference, 1998.

The first generation of field-ready WINS devices and software were fielded in 1996 and later in a series of live-fire exercises. The LWIM-II demonstrated the feasibility of multihop, self-assembled, wireless network nodes. This first network also demonstrated the feasibility of algorithms for operation of wireless sensor nodes and networks at micropower level. The original WINS architecture has been demonstrated in five live fire exercises with the US Marine Corps as a battlefield surveillance sensor system. In addition, this first generation architecture has been demonstrated as a condition based maintenance (CBM) sensor on board a Navy ship, the USS Rushmore.

Prior military sensor systems typically included sensors with manual controls on sensitivity and radio channel selection, and one-way communication of raw data to a network master. This is wasteful of energy resources and inflexible. In the LWIM network by contrast, two-way communication exists between the sensor nodes and the master, the nodes contain signal processing means to analyze the data and make decisions on what is to be communicated, and both the communications and signal processing parameters can be negotiated between the master and the sensor nodes. Further, two-way communications enables consideration of more energy-efficient network topologies such as multi-hopping. The architecture is envisioned so that fusion of data across multiple types of sensors is possible in one node, and further, so that the signal processing can be layered between special purpose devices and the general-purpose processor to conserve power. The LWIM approach to WINS represented a radical departure from past industrial and military sensor network practice. By exploiting signal processing capability at the location of the sensor, communications energy and bandwidth costs are greatly reduced, allowing the possibility of scalably large networks.

The DARPA sponsored a second program involving both UCLA and the Rockwell Science Center called Adaptive Wireless Arrays for Interactive Reconnaissance, surveillance and target acquisition in Small unit operations (AWAIRS), whose genesis was in 1995. Its focus has been upon the development of algorithms for self-assembly of the network and energy efficient routing without the need for masters, cooperative signal processing including beamforming and data fusion across nodes, distributed self-location of nodes, and development of supporting hardware. A self-